SHORT NOTE

Gestalt psychology and the recognition of complex sedimentary structures in geology

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Abstract *Gestalt* is an untranslatable German word that is employed in the visual perception theory based in the psychology of forms. This theory says that it cannot have knowledge of the whole from its parts, but inversely the parts from the whole. The *Gestalt* theory has several laws, which the *Prägnanz* (or simplification) law seems to be the more applicable to the perception of complex sedimentary structures like the hummocky cross stratification (HCS). After several years of geological mapping by experienced geologists this structure could be recognized as a very common sedimentary feature in the intracontinental basins. This recognition only could be made using unconsciously the *Gestalt* approach. In field courses, in the Parnaíba Basin, students only recognized HCS after a simplification according to the *Prägnanz* law. Other structures, like the catastrophic-flood delta mouth-bar section, were detected using the same approach. Detection of oversized features - like giant-ripple cross bedding - from the *Gestalt* approach is also discussed.

Keywords: Gestalt, hummocky cross stratification, Paleozoic, Parnaíba Basin, Paraná Basin.

Resumo *A psicologia Gestalt e o reconhecimento de estruturas sedimentares complexas em geologia.* *Gestalt* é uma palavra alemã intraduzível que é empregada na teoria de percepção visual, baseada na psicologia das formas. Esta teoria afirma que não se pode conhecer o todo a partir das suas partes e sim das partes se chega ao todo. A teoria *Gestalt* possui várias leis, das quais a lei dita *Prägnanz* (ou da simplificação) parece ser a mais aplicável à percepção de estruturas sedimentares complexas como a estratificação cruzada *hummocky* (HCS). Decorreram vários anos de mapeamento geológico por geólogos experientes antes que estas estruturas pudessem ser reconhecida como uma estrutura sedimentar muito comum nas bacias intracontinentais. Este reconhecimento só pôde ser feito usando-se de maneira inconsciente o enfoque *Gestalt*. Nos cursos de campo, realizados na Bacia do Parnaíba, os estudantes só reconheciam a HCS depois de aprenderem a sua simplificação, de acordo com a lei *Prägnanz*. Outras estruturas, como as que caracterizam a seção de barras de embocadura deltaicas geradas por inundações catastróficas, foram detectadas usando-se o mesmo enfoque. O reconhecimento de feições de dimensões exorbitantes – como *ripples* gigantes – é também discutido neste trabalho.

Palavras-chave: Gestalt, Estratificação cruzada *hummocky*, Paleozóico, Bacia Parnaíba, Bacia Paraná.

INTRODUCTION Modernly, in despite of continuous technological innovations, contributing for more and more precise geological observations, the pursuit of geology still rests basically on descriptions. Descriptions are based on perceptions, which are entirely subjective, and depend on the laws of human psychology. “Perceptions without conceptions are blind”, Kant (1781) wrote.

This is particularly true in sedimentary geology. It takes away its character of science and transforms it in art: the interpretative art based on subjective perceptions.

This paper intends to discuss briefly the problem of description from different perceptions, introducing the concept of Gestalt. This concept apparently was never used in Stratigraphy and Sedimentology. It will be tried to explain the problem of hummocky cross

stratification (HCS) which is a very peculiar sedimentary structure occurring everywhere in the Brazilian intracontinental basins. Della Favera (1980) described it by the first time in Brazil in the Parnaíba Basin. At first, what looked to be a particular feature of the Parnaíba Basin, perhaps linked to a paleogeographical control, as it was thought first, showed later on to be very common in the Paraná and Amazon basins, as well as in some pre-rift and rift sections in the continental margin. One puzzling aspect related to the HCS occurrence is that it was not recognized as a unit or even ignored by experienced sedimentary geologists. What would be the cause of such general ignorance?

The answer to that specific question lies in the human psychology. Earlier theories stated that the perception of shapes would be atomist in nature, i.e., it looked for a set after their elements. Opposing to such

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a view, the Gestalt theory was born in the beginning of the twentieth century, after the ideas of German and Austrian psychologists. This theory was initially proposed for psychological studies but along the enlargement of its application field it gained the status of a philosophical thinking.

It can be said that the HCS only could be recognized by the geological community in Brazil after the application of the Gestalt theory, in an unconscious manner.

THE GESTALT THEORY Gestalt psychology is a theory of mind and brain that proposes that the operational principle of the brain is holistic, parallel and analog, with self-organizing tendencies (q.v. www.gestalttheory.net). It opposes to the “atomistic” principle of operation, a common practice in science, which advocates the analysis of isolated parts of the problem in order to reduce its complexity.

This theory states that it is not possible to know the whole after their parts but conversely the parts can be known from the whole. The concept “the whole is more than the summation of parts” is the same to say that “A+B” is not simply “(A+B)” but a third element “C” which possesses its own characteristics (Torrans & Dabbagh, 1999). It is only from the perception of the totality that the brain can perceive, decode and process an image or a concept.

According to the Gestalt theory, knowledge is a continuous act of organizing and rearranging information aiming a given purpose. Therefore, each new information added to the preexisting knowledge is assimilated and lead to a remodeling of all knowledge.

Opposed to the traditional thinking, the Gestalt theory assumes that learning is not a simple accumulation of knowledge but a remodeling of insights, by gradual structuration, leading to a comprehension of problems solving.

There are two different processes in the sensorial perception: a sensation (*Empfindungen*), that corresponds to the pure physical perception of the elements, like the format of an image; and the representation (*Vorstellungen*), an “extra-sensorial” process throughout the grouped elements excite the perception and gain a meaning (the visual shape). The German School does not admit such a dualistic. It states that the two processes occur simultaneously and the “extra sensorial” perception could not be separated from the material object.

Properties of Gestalt Perception

EMERGENCE It is the principle leading to the perception of a given form, even if can be seen initially as a random pattern or a irregular form; the complete form is fully perceived even its perimeter is missing or become undistinguished from other less important perimeters.

Figure 1 reveals the principle of emergence. For those who have never seen this picture before, it appears initially as a random pattern of irregular shapes. A re-

Figure 1 - Human face to demonstrate the principle of emergence in perception. The local regions of this image do not contain sufficient information to distinguish significant form contours from insignificant noisy edges. As soon the figure is recognized as a human face, the contours of the face pop out perceptually, filling in visual edges in regions where no edges are present in the input.

markable transformation is observed in this percept as soon as one recognizes the subject of the picture as the face of Christ. Ink blots individually do not contain the information necessary to distinguish significant from insignificant edges.

REIFICATION Reification is the constructive or generative aspect of perception whereby the experienced percept contains more explicit spatial information than the sensory stimulus on which it is based. Although this is the general perception principle, finalization of incomplete limits and the surface filling are specific components of computational processes.

The reification concept can be extended to more complex illusions where the visual perception may assume a shape and present three-dimensional volumes, as demonstrated by Idesawa, 1991 (apud Lehar, 2004).

Figure 2A shows the most familiar illusions introduced by Gestalt theory (Kanitzsa, 1955). In this figure the triangular configuration is not only recognized as being present in the image, but the triangle is filled-in perceptually, producing visual edges in places where no edges are present.

In geology, this principle is observed when part of the geological features in outcrop is hidden by vegetation or covered by rubble, or any process that does not allow a complete vision. In this case, if the outcrops are not separated each others by long distances, the perception of the complete form is easily observed.

MULTISTABILITY This is the principle where the prolonged viewing of this stimulus results in

Figure 2 - The reification concept as a constructive aspect of perception. All the figures displayed here contain more explicit spatial information than the sensory stimulus on which they are based. A: the Kanitsza triangle; b: B: Tse's volumetric worm; C: Idesawa spiky sphere; D: Tse's sea monster (after Lehar, 2004).

spontaneous reversals, in which the entire percept is observed to invert in depth. According to this principle, perception cannot be considered as simply a feed-forward processing performed on the visual input to produce a perceptual output, but rather perception must involve some kind of dynamic process whose stable states represent the final percept.

In the geological realm, this principle works when two or more processes interact in the interpretation of a outcrop or sample, e.g., an outcrop where tectonic or sedimentary processes can be noted, as fractures or sedimentary structures. In this case, both shapes are stable, but they cannot be visualized or understood simultaneously (Fig. 3). The tectonicist abstracts the sedimentary structures and will focus its attention to fractures, whereas the sedimentologist will force the perception into the first (Lehar, 2004).

INVARIANCE Invariance deals how an object, like a square or a triangle, can be recognized regardless of its rotation, translation, or scale, or whatever its contrast against the background, or whether it is depicted solid or in outline form, or whether it is defined in terms of texture, motion, or binocular disparity.

Invariance occurs in three-dimension as well, through a rotation in depth and uniform invariance in perspective transformations. Readiness of biological vision to handle invariance suggests that it is fundamental for visual perception (Lehar, 2004). Invariance is

Figura 3 – Multistability principle and reversals of stable forms due to prolonged viewing. A: The Necker cube demonstrates multistability in perception; B: This figure shows how large regions of the percept flip coherently between perceptual states (Lehar, op. cit.).

also fundamental to the geological perception. Process and form are independent from scale. The recognition of oversized features depends only of the view point.

Recognition of sedimentary structures can be made regardless they are present in different lithological units, deformed or disposed into apparent sections.

Laws of Gestalt The Gestalt theory proposes some laws that rule the human perception of forms. They are nothing less than conclusions about the natural brain behavior acting during the perception process.

These laws are cited in Wikipedia (the free Encyclopaedia in Internet):

*Prägnanz*¹ law: probably it is the more important law. It states that the forms should be perceived by their simpler character;

Similarity law: similar objects tend to be grouped. The similarity may happen in the object color, in texture or element mass sensation;

Proximity law: the grouping is made based on the distance the elements are from others;

Good continuity law: it is related to the coincidences of directions or alignment of forms; *Closure law*: a good shape is completed if it is closed itself, forming a limited figure. Mind adds missing elements to complete a figure;

Past experience law: it says that some forms only could be understood if there is a previous conscience of its existence. For the Christian believers, the phrase “who see me will never forget” applied to human face, as drawn in figure 1, makes sense, but could be also be applied to any complex form perceived from the Gestalt theory.

HISTORY OF THE “DISCOVERY” OF HCS IN BRAZIL AND LATER DEVELOPMENTS

In 1979, Petrobras, the Brazilian oil company, was interested in training Brazilian geologists in facies and depositional systems. Therefore the Exploration Manager, Mr. Coutinho, ordered that a group of geolo-

¹ *Prägnanz* means expressivity and should not be translated as pregnancy.

gists, including Jorge Della Favera, Miguel Uliana and Ubirajara Mello, should go to the Parnaíba Basin, in the State of Piauí, Brazil, and assessed the local conditions to install a field course on facies and depositional systems, similar to one taught by Emiliano Mutti in Spain. By the guidance of Mello, the group began studying the fluvial sediments of the Serra Grande Group, near the town of Jaicós. Afterwards they moved to the Pimenteira Formation outcrops, near Picos. There they face a something weird facies association. They thought initially that such an association would be fluvial in nature due to the red color of sandstones. Della Favera has had a former contact with the HCS during a SEPM field trip in Texas in 1978 and later on in the South Pyrenees Basin, with the so-called “Campbell’s truncated-wave ripples” (law on the past experience). With some difficulty the group recognized the HCS in the first Pimenteira outcrop and has been shown as a common feature in the rest of outcrops near Picos. As soon as they moved upwards in the stratigraphic column, new HCS recognitions were made. After this field trip, the group approved the location for the facies and depositional systems course, and concluded that HCS was present in all the lithostratigraphic units in the Parnaíba Basin, a surprising finding to them. As such a structure has not been reported previously in Brazil, Della Favera thought it was probably due to special Parnaíba Basin paleogeographical conditions. Della Favera announced the discovery in the Brazilian Geological Society Meeting in 1980. During more than ten years, several groups of Brazilian geologists, including University professors, attended that courses which were conducted by Jorge Della Favera and Rodi Ávila Medeiros. In this period, the students’ behavior before the HCS recognition was always the same: they only recognized the structure after a simple drawing by themselves of its basic properties (*Prägnanz* law, Fig. 4). The Pimenteira red color always masked interpretations. That color simply results from surface pyrite oxidation, which is a common mineral in the Pimenteira shales.

In 1980, Della Favera was charged to make a geological guide to the Sergipe-Alagoas Basin. He was amazed by seeing uncountable HCS in practically every unit studied. As the idea at that time that HCS would develop only in marine settings it looked weird that this structure would occur also in non-marine units. When he recognized the HCS pattern on a tiled wall in a restaurant, he thought he was becoming out of his mind. However, it can be realized now that at that moment he had assimilated completely the HCS Gestalt. From this experience, it is understandable the enthusiasm of Roger Walker in painting and distributing t-shirts with the HCS icon in the SEPM Research Conference on Modern Shelf and Ancient Cratonic Sedimentation, 1980 (Dott & Byers 1981).

Retired from Petrobras, in 1992, Della Favera started to study the Paraná Basin coal section. During field trips, he realized that HCS was ubiquitous and probably would be the commonest facies in that basin.

Figure 4 – Basic image for the application of the Prägnanz law of the HCS Gestalt. The main elements to be followed are 1) the 90° phase difference of successive wavy sets; 2) wavy laminae are parallel to the basal truncation surface (coarse lines) and are truncated by the next wave trend. Wave-truncated laminae are the main elements that close the sedimentary structure by application of the closure law. Students on facies and depositional systems in the Parnaíba Basin only recognized the HCS structure and incorporated its Gestalt after drawing this sketch by themselves. In this scheme, other elements as lithology, the structure size, the graded-bed character, and the vertical trend of decreasing in crest spacing and increasing height, are not taken on account.

This fact led him to think what would be the reason that the former researchers, - mainly the late Rodi Ávila Medeiros, who was a keen sedimentologist, - failed in not describing HCS, because they did not have a past experience to see it as a unit defined by the whole. In this period, the most amazing finding was to discover that the coal, in the Permian section, in southern Brazil presents HCS (Della Favera & Chaves 1977; Begossi & Della Favera, 2002 – Fig. 5).

PROPERTIES OF HCS IN TERMS OF THE GESTALT PSYCHOLOGY

HCS is a sedimentary structure very peculiar in shape. In figure 6, there is an ideal representation of HCS, as drawn by Duke (1982). Figure 7 represents a common form in the Pimenteira Formation. However, this configuration is not always present in outcrops but HCS can be detected even in an incomplete character.

Their individual (atomistic) elements are the following: (1) Sharp base; (2) Overall fining upwards (graded bed); (3) Basal carpet of coarse or conglomeratic grains, fossils, and/or mud clasts; (4) Adjacent convex and concave low-angle curved laminae; (5) Crest spacing decreases upward from basal parallel laminae (infinite crest spacing); (6) Ripple height increases upward from basal parallel laminae (height = 0) to “knitted” ripples in the top; (7) Truncations or low-angle terminations. (8) Directional sole marks.

Additionally, a plane-bedding, “flysch”-like geometry, should be mentioned, at least for mud-inter-layered sandstones, in distal settings. This character, similar to that of turbidites, led Della Favera (1990) to call such a bed as an “oscillatory turbidite” (Fig. 8). Some of these individual elements can be used to detect

Figure 5 – Coal mixed with carbankerite showing microhummocky cross stratification. Note vitrain disposed on the settings tops. Faxinl Mine, Bujtiá, Rio Grande do Sul (Brazil) (Photograph from author).

the HCS Gestalt using the above-mentioned laws.

The origin of HCS evolved from the classical storm-layer theory (Harms *et al.*, 1975.) to a turbidite-like, generated by an igniting turbidity current in a continental environment during a catastrophic flood (Mutti *et al.* 1996). Such a current would form HCS on shelf and turbidites in deep-water.

Using Mutti *et al.* model for catastrophic-floods dominated deltas (Fig. 9), it is possible to recognize this Gestalt in several outcrops in the Paraná Basin. Figure 10 presents a view of interlayering of sigmoids and HCS that passes to climbing ripples towards the profile top.

FACIES ANALYSIS AND GESTALT PSYCHOLOGY The adoption by sedimentary geologists of the so-called “Facies Geology”, started with the DeRaaf *et al.* (1965). It represents the abandon of an atomistic

way of summation of simple percepts and the assumption of a Gestalt approach.

Previously to 1971, in Brazil, Petrobras has developed an atomistic approach for describing well cores. It consisted of detailed descriptions, millimeter by millimeter, of lithologic components of cores. The alleged reason of this detailed approach was to optimize data collecting from these expensive data sources. Later on, Klein *et al.* (1972) made descriptions based on facies by the first time in Brazil, studying cores from wells of the Recôncavo Basin. Initially, they have created 120 facies that were reduced to 12 at the end of the project. Today the facies approach is largely utilized in core and outcrop descriptions.

The same atomistic approach is still employed by petroleum reservoir engineers in core sampling for collecting statistical data on reservoir properties.

Figure 6 – Scheme of hummocky cross stratification, Duke (1982).

Figure 7 – HCS in a Pimenteira Formation outcrop in the town of Picos, Piauí, Brazil. This sedimentary structure follows the definition by Harms *et al* (1975): graded bedded, low-angle wavy laminae and crest-spacing greater than 1m (Photograph from Della Favera, 1979).

Figure 8 – HCS in a Poti Formation outcrop, near the town of Floriano, Piauí, Brazil. This bed was called by Della Favera (1990) a “oscillatory turbidite” for a similarity with the Bouma sequence. Crest spacing decrease and height increase are the more conspicuous characters.

Figure 9 - Scheme of facies relationships for a catastrophic-flood dominated delta front (Mutti et al. 1996). This facies association should be regarded as a Gestalt.

Figure 10 – Gestalt of a catastrophic-flood dominated delta-front facies (Mutti et al., 1996). Note the interlayering of sigmoids (bottom and top) and HCS. Lapa Sandstone, Campo Mourão Formation (Carboniferous). Gruta do Monge (Monk’s Cave), Lapa, Paraná.

THE PERCEPTION OF OVERSIZED SEDIMENTARY FEATURES After the Scablands controversy (Allen et al., 1986), geologists became aware that sedimentary features greater than the normal human scope do exist in nature. In the “normal” scope, such sedimentary structures are reduced to normal-sized features, as sigmoidal lobes, disposed on a string, forming oversized ripples (Fig. 11).

This problem exceeds the Gestalt psychology because “parts” are the same as “wholes” (the whole is contained in the parts). The perception of the major “whole” is just a question of intuition to choose the appropriate view point.

Acknowledgements The authors are indebted to Dr Egberto Pereira and Dr. Hernani A.F. Chaves, who read the first version of this paper.

Figure 11 – String of sigmoidal lobes depicting a ripple geometry with 15m ripple-spacing and 2m height. Cabeças Formation, BR-343 Highway, Km 168,5, near Piracuruca, Piauí

References

- Allen J.E., Burns M., Sargent S.C. 1986. *Cataclysms on the Columbia. Features produced by catastrophic Bretz floods in the Pacific Northwest*. 3rd ed, Portland, Oregon, 208 p.
- Begossi R. & Della Favera J.C. 2002. Catastrophic floods as a possible cause of organic matter accumulation giving rise to coal, Paraná Basin, Brazil. *International Journal of Coal Geology*, **52**(1-4):83-89.
- Della Favera J.C. 1980. Reconhecimento de novas fácies e ambientes deposicionais na Bacia do Parnaíba. In: SBG, Congresso Brasileiro de Geologia, 31, *Seção de Breves Comunicações*, pg. 271.
- Della Favera J.C. 1990. *Tempestitos da Bacia do Parnaíba. Um ensaio holístico*. Porto Alegre, Tese de Doutorado, Instituto de Geociências, UFRGS, 243p.
- Della Favera J.C. & Chaves H.A.F. 1977. Estratificação cruzada hummocky no carvão do Sul do Brasil. In: CRONOPAR, 3, Barra do Garças, MT, *Boletim de Resumos*, p. 4.
- Dott R.H. Jr. & Byers C.W. 1981. SEPM Research Conference on Modern Shelf and Ancient Cratonic Sedimentation. – The Orthoquartzite Problem Revisited. *Journal of Sedimentary Petrology*, **51**(1):338-348.
- Duke W.L. 1982. The “Type-locality” of hummocky cross-stratification: the storm-dominated Silurian Medina Formation in the Niagara Gorge, New York and Ontario. In: Ontario Petrol. Inst. Inc. Conf. Tech. Paper, 21 st., *Ann.*, v.2 p.1-31.
- Harms J.C., Spearing D.R., Walker R.G. 1975. *Depositional environments as interpreted from primary sedimentary structures and stratification sequences*. Soc. Econ. Paleont. Mineral. Short Course n. 2 (lecture notes), 161p.
- Kanitzsa G. 1955. Margini quasi-percettivi in campi con stimolazione omogenea. *Rivista di Psicologia*, **49**(1):7-30.
- Klein G. Dev., De Mello U., Della Favera J.C. 1972. Subaqueous gravity processes on the front o Cretaceous deltas, Recôncavo Basin, Brazil. *Geol. Soc. of America Bull.*, **83**:1469-1492.
- Lehar S. 2004. Gestalt Isomorphism and the Primacy of Subjective Conscious Experience: A Gestalt Bubble Model. *Behavioral Brain Sciences*, **26**(4):375-444.
- Mutti E., Davoli G., Tinterri R., Zavala C. 1996.– The importance of ancient fluvio-deltaic systems dominated by catastrophic flooding in tectonically active basins. *Estratto da Memorie di Scienze Geologiche* (Padova), **48**:233-291.
- Torrans C. & Dabbagh N. 1999. Gestalt and Instructional Design. Disponível em: http://chd.gse.gmu.edu/immersion/knowledgebase/strategies/cognitivism/gestalt/gestalt_h_, accessed in 09/06/2005.
- Wikipedia 2005. *Gestalt Psychology*. Disponível em: <http://wikipedia.org/wiki/Gestalt-perception>, accessed in 09/06/2005.
- Wikipedia 2005, Gestalt theory. Disponível em: www.gestalttheory.net, accessed in 09/06/2005.

Manuscript AE 002-2006

Submitted on 04 January 2006

Accepted on 01 December 2007